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UPPER MISSISSIPPI RIVER BASIN MODELING SYSTEM PART 1: SWAT INPUT DATA REQUIREMENTS AND ISSUES

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ABSTRACT

A modeling system has been constructed around the Soil and Water Assessment Tool (SWAT) for the Upper Mississippi River Basin (UMRB), which covers over 491,000 km^2 in parts of eight states in the north central U.S. The SWAT modeling system is designed to assess alternative management and/or land use scenarios, which have the potential to result in improved water quality within the UMRB and in the Gulf of Mexico. Key data sources for the modeling system include the U.S. Department of Agriculture (USDA) Natural Resources Inventory (NRI), the USDA Agricultural Resource Management Survey (ARMS), and Conservation Tillage Information Center (CTIC) tillage survey data. The development of SWAT UMRB baseline land use, crop rotation, tillage, fertilizer application, climate, and soil input data from these and other data sources will be described, as well as the process of generating hydrologic response units (HRUs) which are the basic spatial units required for a SWAT simulation. Issues related to differences between alternative data sources will also be discussed including: (1) differences in overall land use distributions reported in the NRI versus those available from U.S. Geological Survey (USGS) land use data, and (2) the distributions of conservation tillage reported between ARMS and CTIC.

8.1.   INTRODUCTION

The Mississippi River Watershed covers 3.2 million km^2 across parts or all of 31 U.S. states and two Canadian provinces (Figure 1). Excess nitrogen, phosphorus, and sediment loadings have resulted in water quality degradation within the Mississippi and its tributaries. The nitrate load discharged from the mouth of the Mississippi River has also been implicated as the primary cause of the Gulf of Mexico seasonal oxygen-depleted hypoxic zone (Figure 1), which has covered an extent equal to or greater than 20,000 km^2 in several recent years (Rabalais et al., 2002; Turner et al., 2005). Approximately 90% of the
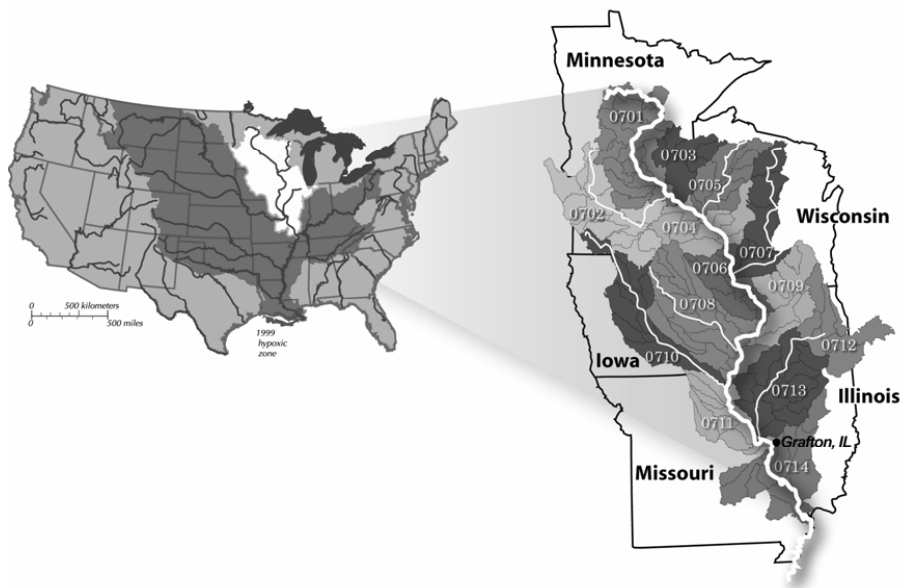
Fig. 1.   The location of the Upper Mississippi River Basin (UMRB) within the Mississippi River Basin, the 14 major 4-digit subwatersheds and 131 8-digit subwatersheds within the UMRB, and Grafton, IL within the UMRB.

nitrate load to the Gulf is attributed to nonpoint source pollution. A significant portion of this load originates from the Upper Mississippi River Basin (UMRB), which covers only 15% of the total Mississippi drainage area (Figure 1). Goolsby et al. (1999) estimated that the UMRB was the source of nearly 39% of the Mississippi nitrate load discharged to the Gulf between 1980 and 1996; 35% of this load was attributed solely to Iowa and Illinois tributary rivers for average discharge years during the same time period (Goolsby et al., 2001). Schilling and Libra (2000) further estimated that annual export of nitrate from Iowa surface waters was about 25% of the nitrate that the Mississippi river delivers to the Gulf of Mexico, despite Iowa occupying less than 5% of its drainage area. A simulation system has been developed using the Soil and Water Assessment Tool (SWAT) model (Arnold and Forher, 2005) to address these UMRB water quality issues, by providing insights that could help mitigate nutrient and sediment losses from UMRB cropland and pastures. The modeling system components, preliminary baseline evaluation, and selected scenario results are reported here and in three companion papers as a 4-part study. The objectives of part 1 of this study are to describe: (1) components of the modeling system, (2) key sources of data, and (3) issues and problems pertaining to currently available data sources.

8.2.   WATERSHED DESCRIPTION

The UMRB extends from the source of the Mississippi river at Lake Itasca in Minnesota to a point just north of Cairo, Illinois. The total drainage area is nearly 492,000 km², which lies primarily in parts of Minnesota, Wisconsin, Iowa, Illinois, and Missouri (Figure 1). The

assumed UMRB outlet for the modeling system is Grafton, Illinois, which lies just above the confluence of the Mississippi River and Missouri River and covers an area of 447,500 km^2 that drains approximately 90% of the entire UMRB. The major UMRB land use categories shown in Table 1 are based on land use data obtained from the USDA 1997 National Resources Inventory (NRI) database (http://www.nrcs.usda.gov/technical/NRI/; Nusser and Goebel, 1997). According to the 1997 NRI, the dominant land areas are cropland (42%), forest (20.2%), and pasture/hay/range (18.6%); the portion of the pasture/hay/range category that is planted to alfalfa is assumed to be cropland and is simulated in the modeling system as a five-year rotation of two years of corn and three years of alfalfa. The total NRI UMRB agricultural area (cropland, pasture/hay/range, and Conservation Reserve Program (CRP) land) is estimated to be 64.6%, which is slightly lower than the estimate of 67% provided by NAS (2000) and an estimate of 66% derived by C. Santhi (2004, Unpublished research data, Blacklands Research and Extension Center (BREC), Temple, TX) from the USGS 1992 National Land Cover Database (NLCD), which is described by Vogelmann et al. (2001). No actual land use data is provided in the NRI for the federal land category. Based on comparisons with federal land maps (http://nationalatlas.gov/fedlandsprint.html) and other land use maps, it was assumed for the modeling system that the federal land located in the Minnesota, Wisconsin, Illinois, and Missouri (8,738 km^2) was forest and that the remaining federal land area in Iowa, South Dakota, Indiana, and Michigan (756 km^2) was wetland (further adjustments to wetland are described in the Data Issues section.

Table 1. Distribution of Upper Mississippi River Basin land use according to the 1997 National Resources Inventory.

Land Use	Area (km^2)	% of Total Area	Comments
Cropland	210,049	42.7	Row crop and small grains
Pasture/hay/range	91,463	18.6	Includes alfalfa rotated with corn
CRP	16,375	3.3	Conservation Reserve Program
Forest	99,157	20.2	Dominated by deciduous forest
Urban/barren	43,002	8.7	Includes farmsteads & rural roads
Water	14,678	3.0	Streams, reservoirs, etc.
Wetlands	7,647	1.6	Includes only "rural marshland" and rice
Federal land	9,494	1.9	No actual land use data provided
Total	**491,836**	**100.0**	

8.3.   SWAT MODEL DESCRIPTION

SWAT is a conceptual, physically based long-term continuous watershed scale simulation model that operates on a daily time step. In SWAT, a watershed is divided into multiple subwatersheds, which are then further subdivided into Hydrologic Response Units (HRUs) that consist of homogeneous land use, management, and soil characteristics. Flow generation, sediment yield, and non-point-source loadings from each HRU in a subwatershed are summed, and the resulting loads are routed through channels, ponds, and/or reservoirs to the watershed outlet. Key components of SWAT include hydrology, plant growth, erosion, nutrient transport and transformation, pesticide transport and

management practices. Previous applications of SWAT for flow and/or pollutant loadings have compared favorably with measured data for a variety of watershed scales (Gassman et al., 2005). SWAT version 2005 was used for the simulations performed in parts 2-4 of this study. A more detailed description of SWAT is provided in part 2 of this study.

8.4. OVERVIEW OF THE UMRB MODELING SYSTEM

The UMRB simulation framework is comprised of 14 major subwatersheds and 131 subwatersheds (Figure 1) that are consistent with USGS 4-digit and 8-digit Hydrologic Cataloging Unit (HCU) watershed boundaries (Seaber et al., 1987; http://www.nrcs.usda.gov/technical/land/meta/m2143.html), respectively, and the approach used by Arnold et al. (2000). Only 119 8-digit watersheds are used in most analyses, due to the assumption of the UMRB outlet being located at Grafton, Illinois. A schematic of the modeling system is depicted in Figure 2, including the key data flows.
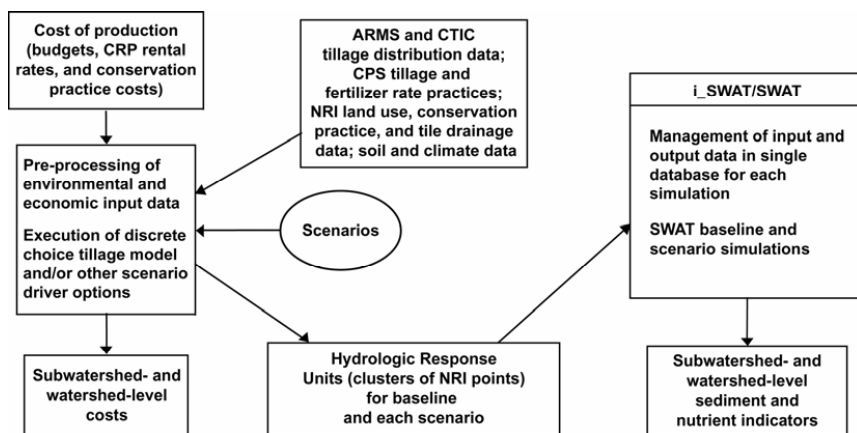

Fig. 2. Schematic of the Upper Mississippi River Basin modeling system.

The primary data source for the modeling system is the 1997 NRI, which contains soil type, landscape features, cropping histories, conservation practices and other information for roughly 800,000 nonfederal land points for the entire U.S. and nearly 114,000 in the URMB. Each point represents areas generally ranging from a few hundred to several thousand hectares in size, which consist of homogeneous land use, soil, and other characteristics. Crop rotations incorporated in the SWAT simulations are derived from cropping histories reported in the NRI. Other land use delineations required for the simulation, including the locations of baseline conservation practices, are also based on NRI data. The distribution of subsurface tile drainage across the region is obtained from the 1992 NRI, which is the only source of such regional tile drainage information.

The distribution of baseline tillage practices across the UMRB are determined as a function of 1997 Agricultural Regional Management Survey (ARMS) data (http://www.ers.usda.gov/Briefing/ARMS/), 1997 Conservation Tillage Information Center (CTIC) data (http://www.ctic.purdue.edu/CTIC/CRM.html), and a discrete choice tillage model (Kurkalova et al., 2006). The specific tillage implement practices used to represent

the different tillage types are drawn from USDA 1990-95 Cropping Practices Survey (CPS) data (http://usda.mannlib.cornell.edu/usda/ess_entry.html). The CPS is also the source of the assumed baseline fertilizer application rates used in the analyses reported in parts 2-4 of this study. Applications of nutrients via livestock manure are currently not incorporated in the modeling system. Baseline precipitation, maximum temperature, and minimum temperature data were obtained for 1979-2004 for 553 climate stations across the UMRB region (Y. Lain. 2005. Personal communication. Illinois Water Survey, Champaign, IL). These climate data were furthered processed to obtain single average climate input records for each 8-digit watershed. The soil layer data required for the SWAT simulations was obtained from a soil database that contains soil properties consistent with those described by Baumer et al. (1994), that includes ID codes that allow direct linkage to NRI points.

The development of a SWAT UMRB simulation requires the creation of HRUs within each 8-digit watershed included in the analysis. The HRUs required for the SWAT UMRB baseline simulation are created by aggregating NRI points together on the basis of common soil, land use, and management characteristics (Figure 2). Common soil types were aggregated at 8-digit level via a statistically-based soil clustering process that was performed for NRI-linked soils for most of the U.S. (Sanabria and Goss, 1997), which reduced the number of possible of HRU combinations. For land use, all of the points within a given category such as forest, urban, pasture, and land set aside (defined as part of the Conservation Reserve Program or CRP) land were clustered together, except for the cultivated cropland. For the cultivated cropland, the NRI points are first aggregated into 13 crop rotation land use clusters within each 8-digit watershed, based on the NRI cropping histories. These crop rotation aggregations are then subdivided based on permutations of rotations; e.g., corn-soybean versus soybean-corn. The final step of developing HRUs required aggregation across NRI points according to the management characteristics such as tile drainage (yes or no), conservation practices (terracing, contouring, and/or strip cropping), and tillage type. The discrete choice tillage economic model (Figure 2), in conjunction with the ARMS and CTIC data, is used to determine whether an NRI point should initially be classified as being managed with conventional or conservation tillage. Further random assignments are then made to assign each NRI point to one of four specific tillage types (as a function of residue cover): conventional (0-15% residue), reduced (15-30% residue), mulch (>30% residue), or no-till (no tillage implement passes).

The creation of HRUs for alternative land use and management practice scenarios differs only in the manner of how shifts in land retirement, conservation practices, and/or other management practices are assigned to specific NRI points, prior to the HRU aggregation step (Figure 2). Assignment of tillage practices to specific NRI points can again be performed with the discrete choice tillage model. Alternative approaches have to be used to determine how other conservation practices should be assigned to NRI points; these can also be used to assign tillage practices. The conservation practice algorithm described in part 3 of this study is one alternative that can be used to assign both tillage and other conservation practices to the NRI points.

Two approaches have been used to generate HRUs for the SWAT UMRB simulations: (1) a 5,000 acre (1,969 ha) limit for the minimum HRU size, and (2) no minimum size limit for the HRU size. The "5,000 acre limit" alternative results in about 2,800 HRUS being generated for the entire URMB, and was the option that used for both the baseline and scenario SWAT simulations reported in parts 2-4 of the study. This approach greatly reduces the runtime required for the dozens of calibration simulations performed for part 2 of this study, which would run much slower if the unconstrained approach were used

(which generates approximately 18,000 HRUs for the entire UMRB). However, the simpler approach results in some significant inaccuracies in the total cropland and other land use that is ultimately simulated for the region (Table 2), due to the exclusion of many smaller cropland areas. Thus, the unconstrained HRU generation approach will be used for forthcoming final UMRB baseline calibration and validation simulations, and for future scenarios performed with the modeling system.

Table 2. **Resulting simulated land use areas for the 5,000 acre HRU cutoff approach versus the unconstrained HRU approach, for the entire UMRB region (including watershed 0714 (Figure 1) below Grafton).**

Land use category	5,000 acre HRU cutoff approach		Unconstrained HRU approach	
	Total area (km^2)	% of total UMRB area[a]	Total area (km^2)	% of total UMRB area[a,b]
Cropland	187632	38.4	249620	51.1
CRP	22273	4.6	17568	3.6
Pasture	68519	14.0	53240	10.9
Forest	146972	30.1	122267	25.0
Urban	63075	12.9	45776	9.4

[a]The ultimate percentages of each these simulated land use categories are slightly lower than shown here for both approaches, due to a reduction of these areas to include additional wetland areas that are not accurately accounted for in the NRI (as described in the Data Issues section), and other smaller areas covered by water.

[b]These differences relative to Table 1 are due mainly to alfalfa being shifted to the cropland category and the assignment of federal land to forest

Finally, the modeling system provides the capability to generate costs and environmental indicators at both the UMRB outlet and at the 8-digit and 4-digit subwatershed levels (Figure 2). Costs are generated from relevant economic input data, such as the processing of CRP rental rates as described in the approaches by Kurkalova et al. (2004) and Feng et al. (2005). The environmental indicators, which focus primarily on sediment and nutrient outputs, are generated with SWAT at the subwatershed and entire UMRB levels. The SWAT executions, including the input and output data, are managed with the interactive SWAT (i_SWAT) software (Gassman et al., 2003; http://www.public.iastate.edu/~elvis).

8.5.   DATA ISSUES

The current UMRB modeling system has proven to be a robust simulation tool. The results described in parts 2-4 of this study underscore that the modeling system can be used to effectively evaluate UMRB baseline conditions and alternative land use, management practice, and climatic scenarios. However, it is an ongoing goal to refine the simulation capabilities of the modeling framework, via both improved input data and modeling capability (such as enhancements to the SWAT model). Data uncertainty is a key issue that poses challenges in applying the modeling system to the UMRB. Disparities between alternative data sources and other data problems are discussed here, to highlight the types of data uncertainty that can be encountered when developing a large regional modeling system.

8.5.1. Land Use

The 1997 NRI has proven to be a very flexible source of land use data for the UMRB modeling system. This is particularly true regarding the establishment of crop rotations for UMRB cropland land use based on NRI cropping history information. Simulation of crop rotations is essential in order to accurately reflect nutrient management and other practices in the UMRB that are closely tied to crop rotation patterns. No other currently available land use data source provides the ability to determine crop rotations for the entire region in a straight forward manner. Crop rotations could potentially be developed for Illinois, Iowa, and the Bootheel region of Missouri using remote sensing data collected during 2001-2004, and to a lesser extent with remote sensing data available for Wisconsin during 2003-2004 (USDA-NASS, 2006). Application of this remote sensing data is being investigated at the field tract level for specific watersheds in Iowa for smaller SWAT applications. However, this approach will not be a viable alternative for the larger UMRB applications for the foreseeable future, due to the fact that no data is currently available for Minnesota and most of Missouri.

An obvious weakness of the 1997 NRI land use and other associated data is that it is nearly a decade old, and thus does not reflect more recent land use changes. Smaller annual NRI surveys have since been conducted for at least the three-year period of 2001-2003, but these newer NRI data sets do not provide statistically enough reliable data that can be used in the modeling approach described here (http://www.nrcs.usda.gov/technical/NRI/archived.html). The only other viable sources of consistent land use data for the whole region are the 1992 USGS NLCD, which is obviously even older, and the 2001 National Land-Cover Database (NLCD 2001) that is scheduled to be completed sometime in 2006 (Homer, et al., 2004). Both the 1992 NLCD and 2001 NLCD provide only a single "row crop" category for cropland, and thus neither are a viable source of land use for the UMRB modeling system.

One additional question of interest is how the NRI land use estimates compare with the NLCD approach at the 8-digit and 4-digit watershed levels, and for the entire UMRB. This type of comparison has been performed between the major land use categories reported in the 1992 NRI and 1992 NLCD (C. Santhi. 2006. Unpublished research document. BREC, Temple, TX). The 1992 NRI was used to provide a consistent timeframe for the comparison. The results of the comparison for the entire UMRB are shown in Figure 3 for 11 different land use categories. The row crop category was by far the largest for both land use sources; the NLCD row crop estimate exceeded the corresponding NRI estimate by over 10,000 km^2. The land use area estimates for the water, forest, and pasture/hay categories were relatively close between the two sources. Greater discrepancies were found between the two land use estimates for the small grain, urban, and wetland categories.

The NRI wetland area listed in Table 1 (7,647 km^2) consists primarily of rural marshland and is significantly smaller than the 30,498 km^2 wetland area reported in the 1992 NLCD for the UMRB. Additional wetland area, that is not categorized as rural marshland, is identified in the NRI in the form of vague acreage ranges of ≤ 1, ≥ 1-5, 5-20, or ≥ 20 ac that are imbedded within specific NRI points. Thus it was assumed that the total wetland area should be set as close as possible to the NLCD wetland area by: (1) subtracting the wetland area listed in Table 1 and that attributed to federal lands from the total NLCD wetland area, (2) distributing the remaining wetland area within each subwatershed using a set of algorithms that determined how much wetland area should be
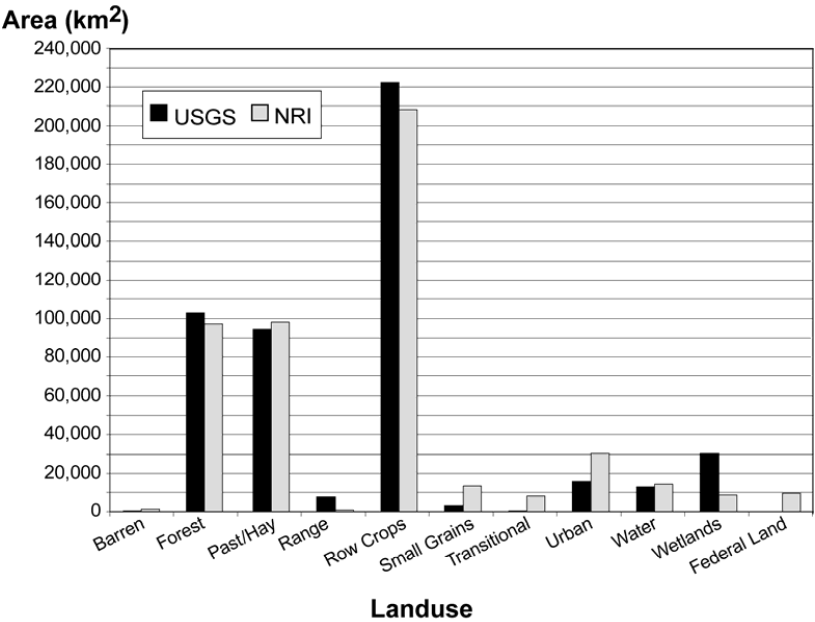
Fig. 3. **Comparison of estimated land areas for key land use categories reported in the 1992 USDA NRI and the 1992 USGS NLCD (C. Santhi, Unpublished research document. BREC, Temple, TX).**

imputed on a given NRI point as a function of the wetland acreage range (≤ 1, ≥ 1-5, 5-20, or ≥ 20 ac) identified for that point, and (3) subtracting the equivalent area, that was attributed to wetland for a specific NRI point, was subtracted from the land use category identified for that point. Thus the ultimate land use distribution incorporated in the modeling system reflects these adjustments to the initial NRI land use distribution reported in Table 1.

8.5.2. Tillage Data

As previously noted, the determination of tillage practice distributions in the UMRB are currently derived from survey data available from both the ARMS state-level data and the CTIC county-level data. The decision to use a combination of both data sources reflects the fact that there are considerable differences in the estimates of specific tillage type adoption for various crop and UMRB subregion combinations. This is illustrated by the conservation tillage adoption rate comparisons shown in Table 3 for the entire UMRB and for selected 4-digit watershed subregions (Figure 1). As can be seen from these examples, the differences between the corn and soybean adoption rates often exceeds 10% or more, and there is nearly a 20% difference between the two corn estimates for subregion 7100. The adoption rate estimates for the entire UMRB are generally in better agreement, although there is still a 10% difference in the two values reported for corn.

Table 3. **1997 conservation tillage adoption rates as reported by ARMS[a] and CTIC[b] for the entire Upper Mississippi River Basin (URMB) and selected individual 4-digit watersheds or combinations of 4-digit watersheds.**

Data Source	Crop	UMRB	7010, 7020, 7030	7060, 7070, 7080	7100	7110
		------------------------------- % (No. samples) -------------------------------				
ARMS	corn	44 (686)	12 (133)	53 (229)	56 (85)	24 (54)
CTIC	corn	34 (297)	22 (64)	45 (87)	37 (44)	35 (26)
ARMS	soybean	53 (600)	39 (182)	57 (171)	47 (105)	53 (56)
CTIC	soybean	60 (293)	44 (61)	71 (86)	64 (44)	61 (26)
ARMS	other crops	56 (99)	-	-	-	-
CTIC	other crops	32 (273)	-	-	-	-
ARMS	all crops	48 (1385)	25 (280)	55 (407)	52 (190)	45 (131)
CTIC	all crops	44 (863)	30 (189)	56 (247)	50 (117)	51 (76)

[a]1997 Agricultural Regional Management Survey state-level survey data (http://www.ers.usda.gov/Briefing/ARMS/).

[b]1997 Conservation Tillage Information Center county-level survey data (USDA, 2006).

At present, there is no clear way to establish which of the two data sources would be considered to be the most reliable. The CTIC survey relies on expert opinion and supporting transect surveys of selected cropland areas (typically drive-by surveys of residue on crop fields), to determine the distribution of five different tillage categories at the county level (Hill, 2006). Hill (2006) states that "users can have 90% or more confidence in the accuracy of the results" when using the transect method. However, Thoma et al. (2004) report that the transect survey method resulted in only 45 and 50% accuracy rates for soybean and corn, respectively, when compared for the five tillage levels against remote sensing data for 11 counties in south central Minnesota (the accuracy rates increased to 77and 70% for soybean and corn when only 2 or 3 tillage categories were used). The ARMS survey is designed to be statistically reliable at the state level; aggregation of the ARMS data to the 14-digit level may be statistically less valid, but it is unclear if this is less reliable than the CTIC data. It is likely that both data sources have strengths and weaknesses, and thus the approach of using both sets of estimates to support the assignment of specific tillage types to the UMRB NRI points is believed to be the best way to rectify the current inconsistencies. The discrepancies noted here indicate that there is a need for improved estimates of regional tillage practice distributions.

8.5.3. Tile Drainage

Subsurface tile drainage is a key conduit of nitrate transport to the Mississippi River Basin (Randall and Mulla, 2001), including several million acres of tiled drained cropland in the UMRB. Current estimates of tile drained areas in the UMRB (Figure 4) are based on data provided by the 1992 NRI. At present, no other data source that provides estimates of the regional distribution of tile drained lands has been identified, for either the UMRB or major subregions (e.g., specific states or 4-digit watersheds). The 1992 tile drained cropland is linked into the modeling system via a coupling between the 1992 and 1997 NRI points. The fact that collection of tile drained acreage was discontinued for the 1997 NRI is an indicator of the difficulty of accurately estimating such areas. Anecdotal evidence suggests that tile
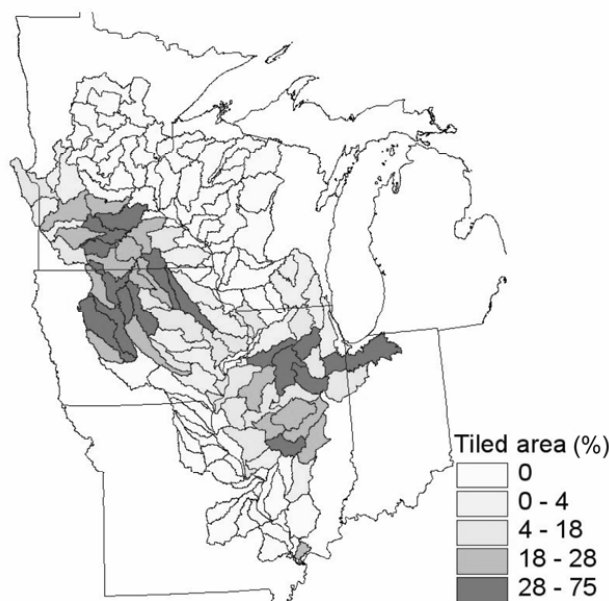
Fig. 4. Distribution of tile drainage by 8-digit watershed in the Upper Mississippi River Basin according to the USDA 1992 National Resources Inventory (NRI).

drained areas have increased across Iowa during the past decade, especially in north central and eastern Iowa. Similar trends may have occurred in other UMRB subregions. Thus there is little doubt that the 1992 NRI underestimates the actual area of tile drained cropland in the UMRB. Quantifying the true extent of tile drained cropland is a critical data gap that needs to be filled, in order to more accurately perform water quality assessments with the modeling system described here and with other methods.

8.5.4. Fertilizer Inputs

The current simulated nitrogen and phosphorus fertilizer application rates are based on the 1990-95 USDA CPS survey data as previously noted. More recent 1996-98 ARMS survey data and 1997 fertilizer sales data are being investigated as possible fertilizer application rate data sources to replace the older CPS data. However, it is noteworthy that total nitrogen fertilizer sales plateaued in the late 1980s and have remained essentially constant since that time (Randall and Mulla, 2000), which implies that the older CPS data should be a reasonable reflection of total fertilizer inputs to UMRB cropland.

A comparison of 1997 nitrogen fertilizer sales data (M. Burkart. 2002. USDA Agricultural Research Service (ARS), National Soil Tilth Lab., Ames, IA) and average 1996-98 ARMS nitrogen application rates does reveal other complications in developing appropriate nitrogen application rates for the UMRB simulations (Table 4). The nitrogen

Table 4. Total UMRB nitrogen inputs according to state-level fertilizer sales data, average state-level ARMS spring wheat and corn nitrogen fertilizer application rates, total ARMS nitrogen inputs to UMRB cropland, and the difference between 90% of the total nitrogen fertilizer sales data and the total ARMS nitrogen fertilizer inputs for the five main UMRB states.

State	Total 1997 nitrogen fertilizer based on sales data[a] (t)	90% of the total 1997 nitrogen fertilizer based on sales data[b] (t)	Average ARMS spring wheat nitrogen Application rate[c] (kg/ha)	Average ARMS corn nitrogen Application rate[c] (kg/ha)	Total nitrogen fertilizer inputs to cropland based on ARMS data[d] (t)	Difference between total ARMS N inputs and 90% of the total N sales data (%)
Illinois	923,189	830,870	106	180	901,989	108.6
Iowa	880,770	792,693	0	143	723,659	91.3
Minnesota	648,828	583,945	97	128	505,363	86.5
Missouri	419,415	377,474	116	178	316,823	83.9
Wisconsin	230,395	207,356	96	92	172,493	83.2

[a] 1997 sales data obtained from M. Burkart, USDA Agricultural Research Service (ARS), National Soil Tilth Lab., Ames, IA; represents the relative portion used in the UMRB drainage area in each state.

[b] It is assumed here that 10% of the fertilizer sold in each state will be used for non-cropland applications.

[c] The spring wheat and corn application rates are based on averages for 1996-98 ARMS survey data; corn, and to a lesser degree spring wheat, are the two crops that receive the most nitrogen fertilizer.

[d] Total nitrogen applied to cropland in each of the five main UMRB states, which was calculated by summing up all the nitrogen applied to corn and spring wheat based on the average 1996-98 ARMS application rates (and some other minor crops in Minnesota and Missouri).

sales data reflects the proportion of total fertilizer reported sold in each state during 1997, which would be representative of the area of a given state that is in the UMRB basin area. It is not known exactly what percentage of these total nitrogen sales in each state were applied to cropland. Thus it was assumed that 10% of the sold fertilizer was used for non-cropland applications and the remaining 90% was applied to cropland (mainly corn and spring wheat). The total amount of nitrogen applied to cropland according to the ARMS data was then computed by summing up all the nitrogen applied to corn and spring wheat in each state (and some other minor crops in Minnesota and Missouri), based on the average 1996-98 ARMS application rates (Table 4). The resulting differences between the total nitrogen inputs according to ARMS, relative to the corresponding sales data (90% of total), range from almost 9% greater for Illinois to nearly 17% less for Wisconsin (Table 4). This may imply that the actual nitrogen fertilizer application rates for corn, spring wheat, and other crops are actually higher than what is reported in ARMS for Iowa, Minnesota, Missouri, and Wisconsin, and vice versa for Illinois. However, there is clearly uncertainty in these comparisons due to a lack of data as to how nitrogen is exactly used in each state, especially for non-cropland applications. Further investigation will be carried out to ascertain what is the best choice of fertilizer rate application assumptions for the UMRB baseline conditions.

8.6.   CONCLUSIONS

A modeling system developed for the Upper Mississippi River Basin (UMRB) that provides a basis for evaluating a wide range of alternative agricultural land use and

management scenarios. A key component of the modeling system is the Soil and Water Assessment Tool (SWAT) model, which is used to assess pollutant loadings in response to different scenarios. The system continues to evolve, both in terms of data inputs and changes to the modeling tools including SWAT. Several data weaknesses have been identified here regarding land use, tillage, tile drainage, and nitrogen fertilizer inputs. Some of these problems cannot be immediately resolved and thus sensitivity analyses will be performed to obtain more insight on the effects of ranges of sensitive inputs; e.g., the distribution of tile drained cropland. Updates to the currently used CPS nitrogen and phosphorus fertilizer application rates will be conducted, and applications of manure will be incorporated into the modeling system. Future simulations will also be based on the more refined HRU generation approach, that is not limited by any acreage constraints.

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